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A STUDY OF THE INFLUENCE OF THE GREAT HANSHIN EARTHQUAKE ON HUMAN RESPONSE TO ENVIRONMENTAL VIBRATION DUE TO THE SHINKANSEN

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1. INTRODUCTION

On January 17, 1995, at 5:46 am., a big earthquake of scale M=7.2 hit west part of Japan in which the highest intensity and most severe damage was concentrated in the Southern part of Hyogo Prefecture. As for scale of the earthquake, the ground vibration observed in neighboring district surpassed 500gal in maximum vertical acceleration level [1][2]. The SANYO Shinkansen which services Shin-Osaka and Hakata is part of the approximately 2,000 km Shinkansen railway network all over Japan, runs through earthquake hit area. The Shinkansen railways also suffered damages and the worst area is along the 50km stretch from Shin-Osaka towards Akashi, where elevated sections collapsed and piers were severely damaged in more than 10 places [1][2].

As the Shinkansen railway, which is one of the high speed transportation systems, plays an important role in supporting Japanese economy, priority was given in the reconstruction works and services were restored by the middle of April 1995.

But, as soon as the Shinkansen resumed operation, the number of complaint towards the vibration due to the passing by Shinkansen increased rapidly from the inhabitants of stricken area. Initially, it was thought that this was due to the change of vibration transfer characteristic , or an experience of earthquake caused the people to become more sensitive towards vibration . To confirm these allegations, a study was carried out. Ground vibration levels were measured and the opinion of the inhabitants were taken in both the stricken area and non-stricken area as reference in October 1995.

2. SURVEY

Ground Vibration

Most of the Shinkansen railway is of elevated reinforced concrete structure. The height and width of the structure is 8-10m and 10m respectively and noise insulation walls were installed at most places. Nishinomiya was selected as the study area, since along the Shinkansen railway, almost all of the dwellings suffered damages of which 30% of them were completely damaged. Aioi which is approximately 100 km away from Nishinomiya, where there was hardly any damage to dwellings and to the Shinkansen railway, was selected as reference area.

Four measurement points, located at 12.5m, 25m, 50m and 100m away from the Shinkansen track, were taken on the road which is perpendicular to the Shinkansen railway. At each point a pickup sensor was placed on the road surface and all of the pickup sensors were connected to a datarecorder. The ground vibration was measured in terms of vertical and horizontal acceleration levels from which weighted R.M.S acceleration level [3] was obtained using weighted filter.

Questionnaire

Questionnaire was conducted at Nishinomiya and Aioi to examine the degree of nuisance concerning the vibration due to Shinkansen. In each area, 100 samples were taken where 50 samples were distributed within the 0-50m area and another 50 samples within the 50-100m area from the Shinkansen track. The investigation was conducted through visit interview where some basic data of each interviewee were taken and their opinion regarding the vibration due to passing through Shinkansen were asked. 30% of the interviewee fall into more than 60 years old age group and 20-25% fall into each of the 30, 40 and 50 years old age groups. Approximately 80 % of the interviewees were women.

Each interviewee was asked to respond to each of the questionnaires by selecting one of the given 5 categories of nuisance as follows :-

1. very annoyed 2. annoyed 3. fairly annoyed 4. little bit annoyed
5. not annoyed at all.

The following questions regarding the effect of the vibration due to the passing by the Shinkansen were asked.

a. What is your reaction towards the Shinkansen vibration?
b. How do you feel about the vibration of the doors and windows?
c. How do you feel about the vibration of the tableware and decorations?
d. How do you feel about the vibration of the furniture?
e. How do you describe your irritation?
f. How do you describe the interruption to reading, writing or

concentrating?
g. How do you describe the interruption of your sleep?
h. How do you describe the discomfort of watching television and listening to radio?
i. Do you become more sensitive towards the Shinkansen vibration after the earthquake? (To this question, the answer is either YES or NO)

3. RESULTS

Results of the Ground Vibration Investigation

Fig.1 shows the vertical vibration level with distance in Nishinomiya and Aioi. Although horizontal vibration was measured, it is not shown because it is much smaller than the vertical vibration. The vertical vibration levels for both areas were almost the same between 12.5m and 50m distance from the Shinkansen track. But at 100mpoint, the vibration level at Nishinomiya is greater than at Aioi.

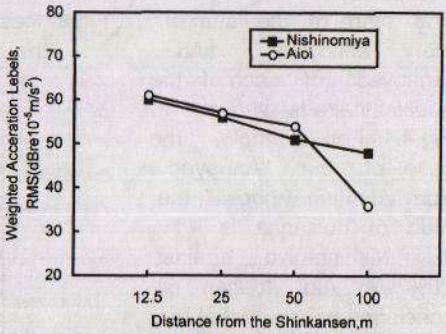


Fig.1. Vibration Attenuation with Distance (vertical vibration)

Fig. 2 shows a result of frequency analysis of vertical vibration level at 12.5 m point. Analysis method was performed by the way of maximum hold on the passage between the front and back of the train. The vertical axis shows a weighted R.M.S. acceleration level in decibels (dB, re;0dB=10^{-5} cm/s^2). The horizontal axis is 1/3 octaveband center frequency, n Hz. The dominant frequency is 8 Hz in Nishinomiya and 16 Hz in Aioi. It is difficult to make comparison between them simply because both vibration levels are different. Coincidentally, 8 Hz in Nishinomiya

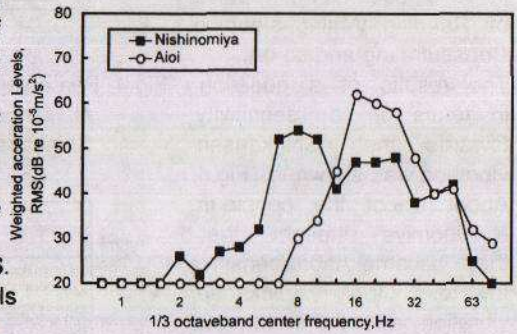


Fig.2. Result of the Analysis of Ground Vibration at Nishinomiya and Aioi

is the most sensitive frequency zone of human response to vertical vibration.

Results of the Questionnaire

Fig. 3, shows the degrees of nuisance for the Shinkansen vibration. It shows that ratio of the sum "very annoyed" and "annoyed" was 57 % in Nishinomiya and 25 % in Aioi. The ratio of the sum of "very annoyed" and "annoyed" of each of the questionnaire is shown in Fig.4. For example, the case of the "Annoyed from Vibrating window ", the ratio of nuisance is 41% in Nishinomiya against 20% in Aioi. It can be concluded generally that the nuisance in Nishinomiya are greater than that of Aioi, especially in psychological influence such as interruptions of Reading, Writing, sleeping, Consentrating and so on.

The results of a question in terms of a sensitivity towards the Shinkansen vibration was shown in Fig.5. About 70% of the people in Nishinomiya thought that they became more sensitive toward the Shinkansen vibration after the earthquake, but in Aioi, the ratio was only 16%.

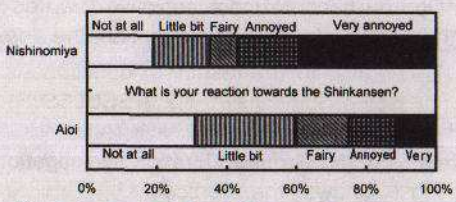


Fig.3. Result of the Nuisance about the Shinkansen

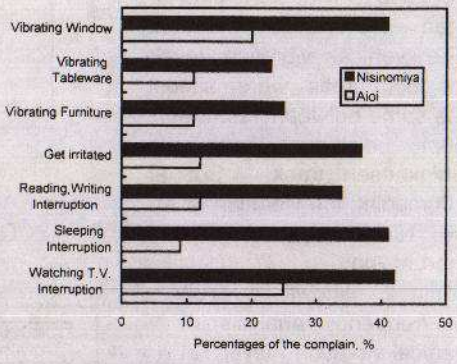


Fig.4. Percentages of Category of Nuisance against the Shinkansen Vibration

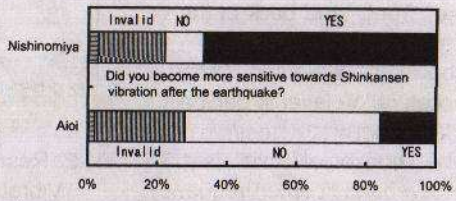
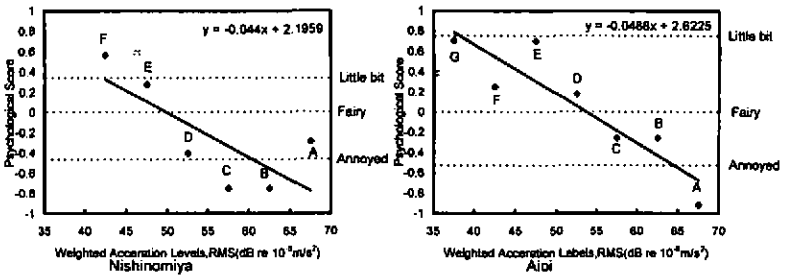


Fig.5. A Comparison of Sensitivity of People living in Nishinomiya and Aioi towards the Shinkansen Vibration

4. DISCUSSION

A lot of information was gathered from the ground vibration investigation. But it is difficult to make any comparison study as there is no available past measured data, especially data before the earthquake.

According to the results of questionnaire, the degree of the nuisance due to the Shinkansen vibration in Nishinomiya was greater than Aioi. In particular, psychological influence such as Irritation, discomfort to reading, writing, sleep interference, etc., were greater than Aioi. It may be due to the difference in the propagation condition of the ground vibration. And also we can conclude that the earthquake has made the people to be more sensitive towards vibration. "Category judgement method [4]", which is one of the "Method of successive categories", was adopted to examine the relationship between the answer of questionnaire and the quantity of physics (vibration levels). Fig.6 shows the result on "nuisance degree for Shinkansen vibration" in Nishinomiya and Aioi. The stimulation was divided at every 5 dB stage into 7 phases from 40 dB following to 65 dB. As can be seen, the inclination of regression line of Nishinomiya and Aioi are almost the same. The intersection point between the regression line and psychological center is taken as the vibration level. From the figure it can be seen that the vibration level for Nishinomiya is approximately 50 dB and 54 dB for Aioi.



A:65-70dB, B:60-65dB, C:55-60dB, D:50-55dB, E:45-50dB, F:40-45dB, G:35-40dB

Fig.6. Relation between the Psychological Score and Vibration Level

5. CONCLUSION

From the ground vibration investigation, vertical vibration levels of points within 50m from Shinkansen track for both study areas were almost the same but at 100m point, the level at Nishinomiya was

approximately 10 dB greater than Aioi. From the frequency analysis, the dominant frequency in Nishinomiya was lower than in Aioi. Further investigation is necessary to confirm whether this condition were caused by the earthquake or something else.

According to the result of the questionnaire, most of the interviewees agree that the Shinkansen vibration became greater after the earthquake in Nishinomiya. The category judgement method results show that the vibration level (where 50% of the inhabitants complained of the Shinkansen vibration) was approximately 54 dB in Aioi and 50 dB in Nishinomiya. If we take the results of Aioi as standard, people in Nishinomiya becomes approximately 4 dB more sensitive. Therefore it can be concluded that the experience of a great earthquake has caused the people in Nishinomiya to be more sensitive towards vibration.

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